Page

TABLE OF CONTENTS: CHAPTER 4 - DETERMINING DESIGN DISCHARGES

CHAPTER 4. DETERMINING DESIGN DISCHARGES

General

Procedures for determining peak rates and volumes of runoff are available in the NEH, Section 4. [17] Procedures for determining channel capacity for irrigation canals and laterals may be found in NEH, Section 15, [18] and for drainage channels in NEH, Section 16 [2].

The adaptation of hydrology will be related to two principles in channel design. One principle is the design of a channel for a peak rate of discharge for a selected frequency of occurrence. The second principle is to determine the rate of discharge required to remove a volume of runoff within a specified time limit.

Flood routing requirements will be different for the two principles. The requirements will differ, too, for other needs as illustrated in Table 4-1.

Procedure for Determining Required Channel Capacity

The usual practice in determining the capacity requirement for channels is to make estimates in the planning stage that are sufficiently detailed for final design. A reconsideration of capacity requirement in the design stage will ordinarily be necessary only if there is a departure from the original plan.

Channels Designed for a Peak Rate and Selected Frequency

These channels are planned and constructed to contain the peak rate of runoff for a design flood of a given frequency. The hydrology for this type of channel involves estimates of local runoff for the design frequency and flood routing through the channel system.

The method of determining runoff and flood hydrographs from subwatersheds for the desired frequency can be selected from those described in NEH, Section 4, [17] Chapters 5, 10, 16 and 18. Chapter 5 describes the use of stream flow data for estimating the rate of discharge. Chapter 10 covers "Estimation of Direct Runoff from Rainfall," for cases where stream flow data are not available or adequate. Rainfall amounts for selected frequencies and durations, as found in the Weather Bureau's Technical Paper No. 40, Rainfall Frequency Atlas of the United States, [19] are generally adequate to provide a basis for an estimate of direct runoff from a specified area. Chapter 16 of NEH, Section 4, [17] covers development of hydrographs, and Chapter 18 describes statistical methods for determining the frequency of flood events.

TABLE 4-1

Investigational Procedure	Flood Routing Required by Project Purpose		
	Containment of a Peak Rate of Runoff of Specified Freq.	Removal of a Volume of Runoff Within a Time Limit	Open Ditch1/ Drainage
1. Determination of design discharge	Channel 2/	None	None
2. Economic evaluation of flood damage reduction			
a. Based on percent chance of occurrence	Channel and overbank 3/	Channel and overbank	None
b. Based on drainage criteria	None	None	None
3. Determination of effects of program on downstream flood peaks	Channel and overbank	Channel and overbank	Channel and overbank 4/

1/ Open ditch for either surface or subsurface drainage.

2/ Channel routing indicates that only storage characteristics of channel are considered in routing computations.

3/ Channel and overbank routing indicates that storage characteristics of both channel and overbank areas are considered in routing computations.

4/ Open ditch channels are frequently designed from drainage criteria which only deals with peak rates of runoff. If a routing is required, design hydrographs must be developed.

The "Convex" routing method described in NEH, Section 4, Chapter 17,17/ is appropriate for establishing the design flood discharge capacity. The permissible mean velocity, channel reach length and the hydrograph of inflow to the reach, are required for channel routing.

A check should be made in every case to determine if the channel will be carrying ground-water flow. If so, an estimate of the discharge

rate of ground-water flow should be added to the design capacities, computed above. NEH, Section 4,[17] Chapter 6, describes the separation of ground-water flow from surface flow of recorded flow data.

Channels Designed to Remove a Volume of Runoff Within a Specified Time Limit

The function of these channels is to remove the volume of runoff causing overbank flooding within a period of time that will prevent damage. The required discharge capacity may be calculated by the empirical procedure described in NEH, Section 16,[2] Chapter 6. These procedures are adapted primarily to locations where comparatively level land area is substantial with respect to the watershed area, where watershed boundaries are difficult to delineate, where it is not necessary to flood route and where channels designed on similar sites have provided adequate protection. It may also be based on a design flood of a given frequency.

Drainage Capacity Related to Frequency

General

It is sometimes necessary to estimate the frequency of protection provided by a channel designed by drainage criteria. The frequency may be related to either a peak discharge or a design flood volume for a specified time interval.

Drainage Capacity Related to Annual Flood Peak Frequency

The frequency, equivalent to drainage criteria, may vary between individual reaches and should be estimated for each reach. The flood frequency equivalent may be obtained by the following procedure from NEH, Section 4.

1. If stream flow data are available, the annual flood peaks, minus ground-water flow, may be related to frequency by the procedure described in Chapter 18. Since the bankfull capacity of the channel can be computed, this discharge can be related to the frequency curve developed from annual flood peaks. Average ground-water discharge that the channel will carry may be estimated by procedure described in NEH, Section 4[17], Chapter 6.

2. If stream flow data are not available, the annual flood may be estimated from rainfall. Obtain rainfall amounts for selected storm durations from Weather Bureau Technical Paper No. 40.[19] Select two or more storm frequencies that will encompass the design channel capacity in all reaches. For each selected

rainfall frequency, compute the volume of direct runoff, develop subwatershed hydrographs, and flood route through channel reaches. Plot the routed peak discharge versus volume of runoff in equivalent inches of depth over the watershed area for the selected frequencies, for each reach. See Figure 4-1. The plotted points are described by a straight line originating at zero. The selected frequencies are shown for their respective volume of runoff. The heavy dash lines with arrows indicate entering the graph with the given design discharge for each reach and reading the volume of runoff. The volume of runoff will in turn relate to a specific storm frequency. This is the storm frequency at which the peak discharge can be contained below a damaging stage.

Drainage Capacity Related to Flood Volume Frequencies

A procedure for determining the frequency of a flood volume that can be removed from the overbank areas by channels with a capacity based on drainage criteria, involves the following assumptions:

1. On-farm drainage and tributary laterals have been constructed with outlets into the designed channel.

2. The volume of storage in the channel network is negligible.

3. The overbank areas are broad and almost flat wherein the variation in the overbank stage with respect to time is relatively small.

Analysis with stream flow data. - - When stream flow data are available, a volume-duration-frequency analysis should be made. Volume-duration-frequency analyses have been provided to many states for streams with drainage areas under 1,000 square miles, by the Central Technical Unit, Hydrology Branch, Washington office, and should be used when available. This analysis can be made according to procedure contained in NEH, Section 4[17], Chapter 18. The analysis can be made for any duration; however, a duration of 24 hours will be used for comparison. Volume-duration-frequency curves are shown for 24, 48, and 72-hour durations in Figure 4-2.

Using the dimensions of the proposed channel, compute the discharge rate for the average overbank stage of flooding for each reach. This computation can best be made at road crossings or other control points where the outflow is confined to the new channel. The average overbank flood stage can usually be estimated within 10 percent at properly selected points such as this. Estimate the average rate of discharge out of the reach by the slope-area

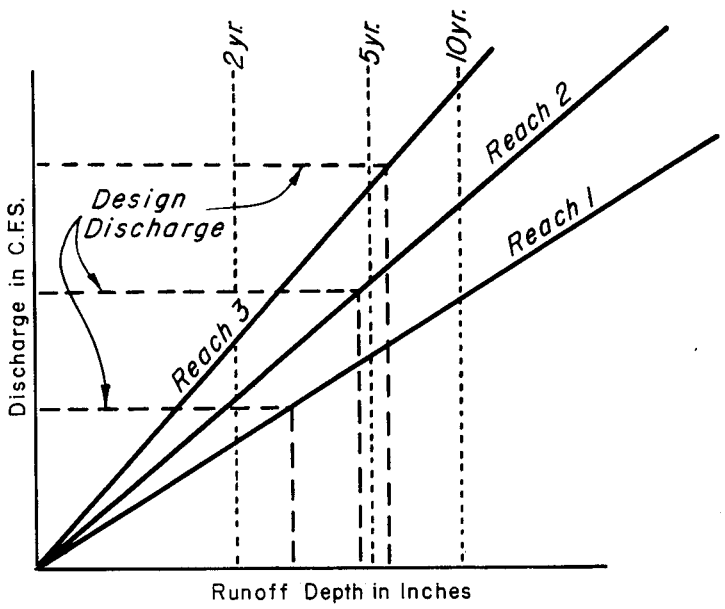

FIGURE 4-1
ROUTED PEAK DISCHARGE VERSUS
AVERAGE DEPTH OF RUNOFF, BY REACH

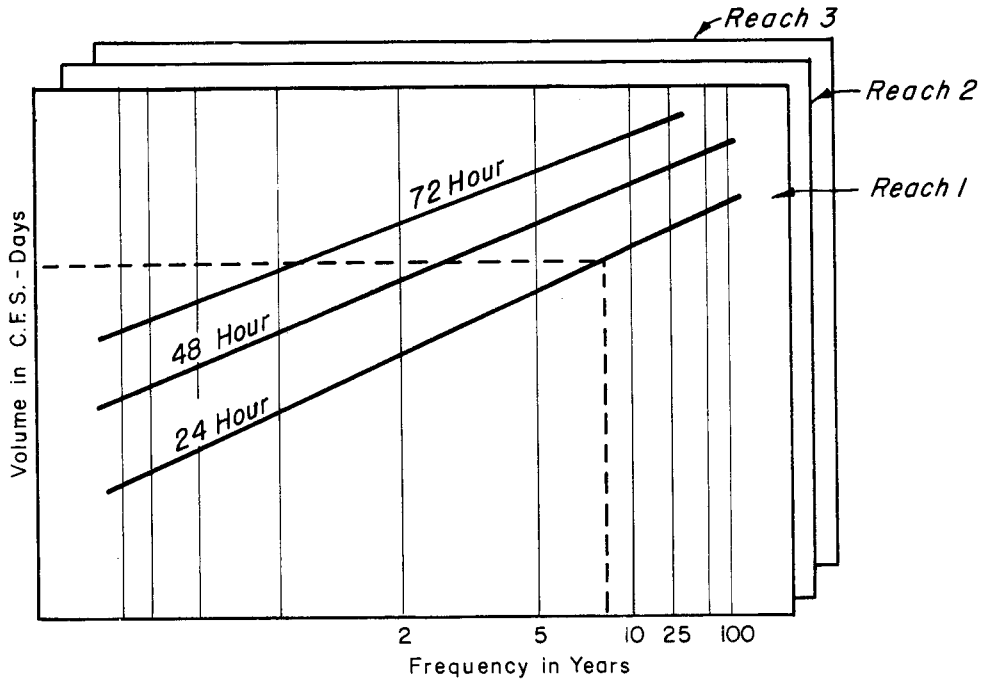

FIGURE 4-2
VOLUME DURATION FREQUENCY ANALYSES

method. This rate of discharge multiplied by 24 hours equals the flood volume removed in cfs-day units. This flood volume is compared with the 24-hour volume-duration-frequency curve from stream flow data to determine the frequency equivalent of the design drainage capacity. (See Figure 4-2.)

The frequency equivalent may be expressed for either of two situations. In many northern states it may refer to the winter and spring snow-melt season or to the summer rain-storm season.

Analysis without stream flow data. - - Where stream flow data are not available, the volume-duration-frequency curves for a 24-hour period may be derived from Weather Bureau rainfall data. The Weather Bureau's Technical Paper No. 40[19] contains maps showing the amount of rainfall expected to occur during a 24-hour period for various frequencies. This may be converted to runoff depth in inches by the procedures in NEH, Section 4[17], Chapter 10. The volume of runoff may be converted to cfs-days by the following conversion factor:

$$\text{Inches depth} \div 0.03719 = \text{cfs-days per square mile}$$

Volume in cfs-days plotted versus frequency provides a graph similar to Figure 4-2. Precipitation amounts for durations longer than 24 hours may be obtained from an analysis of individual precipitation records or by an extrapolation on log paper if this has proven to be valid in the area under consideration. The required frequency equivalent for a channel designed by drainage criteria can be obtained in a manner similar to that for gaged data. See U. S. Weather Bureau TP-49, Two-to-Ten-Day Precipitation for Return Periods of 2 to 100 years in the United States.

This method is limited to channels with drainage areas less than 400 square miles.